

Direct and Residual Effects of Balanced Fertilization in Field Crops of the Pampas

By Fernando García, Miguel Boxler, Jorge Minteguiaga, Ricardo Pozzi, Luis Firpo, German Deza Marin, and Angel Berardo

A long-term fertilization study in the central pampas of Argentina shows significant yield responses to NPS fertilization in corn, wheat, and full season and double-cropped soybean. Differences between the NPS and check treatments have increased over the past six years. Residual effects of balanced NPS fertilization include improved soil P and organic matter levels.

Crop production in the Pampas region of Argentina is generally affected by N and P deficiencies. In recent years, S has also been reported as a limiting nutrient for field crops. Several areas of the Pampas, such as southern Santa Fe and southeastern Córdoba, do not have updated local crop response and soil test calibration data either for N, P, S, or other plant nutrients.

The Southern Santa Fe Region of CREA (Regional Consortium of Agricultural Experimentation) is comprised of 12 groups of 10 to 15 farmers, located in southern Santa Fe, southeastern Córdoba, and northern Buenos Aires provinces in the central Pampas. The consortium's goal is to develop and exchange experiences and information on soil and crop management, farm business management, and product marketing. Total area planted to annual crops by these groups is approximately 200,000 ha. Main field crops are soybean, wheat and corn under rotations including three crops in two years as corn-wheat/soybean (C-W/S), or four crops in three years (C-S-W/S).

Corn and wheat are usually fertilized with N and P, and S fertilization has been incorporated as a standard practice in several fields in the last 4 to 5 years. Fertilizer rates have traditionally been lower than crop nutrient removal, resulting in the continuous depletion of native soil fertility. Traditional fertilization management focuses on the immediate crop. A lack of information exists on the long-term effects of improved fertilization strategies.

In 2000, a long-term fertilization study was established in eleven farmer fields of the CREA Region with the following objectives: i) to determine direct and residual crop responses to the application of N, P, S, and other nutrients including K, Mg, B, Cu, and Zn, ii) to evaluate diagnostic methodologies for N, P, and S fertilization of corn, wheat, and soybean; and iii) to evaluate the effects of nutrient management on soil properties. This article presents a synthesis of the more relevant results observed in the first 6 years of experimentation (2000-2005). Further information is available at Thomas et al. (2002, 2003), Blanco et al. (2004a and b), García et al. (2005a and b, 2006a and b), Boxler et al. (2006), and at the websites www.aacrea.org.ar and www.ipni.net.

Eleven similar experiments were started in the 2000/01 season under corn (**Figure 1**). After the first year, the experiments were divided in two groups: Five sites continued under a C-W/S rotation, and six sites under a C-S-W/S rotation. Soils at the different sites are classified as Typic Argiudolls or Typic Hapludolls. Fields were under continuous annual cropping for

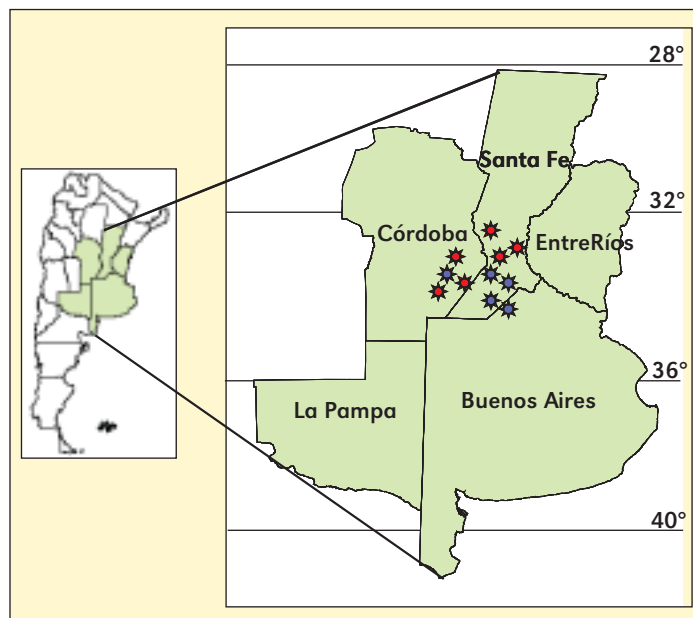


Figure 1. Location of the 11 experimental sites of the on-farm experimental network of the Southern Santa Fe Region of CREA in the central Pampas of Argentina. Blue stars indicate the sites under C-W/S rotation, red stars indicate the sites under C-S-W/S rotation.

5 to 60 years and under continuous no-tillage management for at least 5 years prior to 2000/01.

Treatments included: 1) Check, 2) PS, 3) NS, 4) NP, 5) NPS, and 6) Complete with NPS plus K, Mg, B, Cu, and Zn. Treatments were repeated every year on the same plots to evaluate direct and residual fertilization effects. For all nutrients except N, rates applied to corn, wheat, or full season soybean were equivalent to grain nutrient removal + 10% (**Table 1**). Rates of N were estimated from local experiments with high-yielding crops. No N was applied on soybean. Treatments were set in a randomized complete block design with three replications at each site. Plot size was 10 to 20 m wide by 50 to 60 m long.

Soil analyses for Bray P-1 (0 to 20 cm), $\text{NO}_3\text{-N}$, and $\text{SO}_4\text{-S}$ (0 to 60 cm) were performed every year for selected treatments. Soil organic matter; pH; exchangeable Ca for Bray P-1 (0 to

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; B = boron; Cu = copper; Fe = iron; Zn = zinc; SOC = soil organic carbon; $\text{NO}_3\text{-N}$ = nitrate-N; $\text{SO}_4\text{-S}$ = sulfate-S; ppm = parts per million.

Table 1. Nutrient rates annually applied to each treatment of the on-farm experimental network of the Southern Santa Fe Region of CREA during the period 2000-2005.

	Check	PS	NS	NP	NPS	Complete
N ¹			120-150	120-150	120-150	120-150
P		30-40		30-40	30-40	30-40
K						18
Mg						10
S		20-25	20-25		20-25	20-25
B						1
Zn						2
Cu						2

¹No N was applied in any treatment for full season soybean.

20 cm), NO₃-N, and SO₄-S (0 to 60 cm), Mg, K, and micronutrient concentrations including B, Cu, Fe, Mg, and Zn were determined (0 to 20 cm) at the beginning of the study and 4 years after. Nitrate sap concentration in wheat and corn stems, and chlorophyll meter readings (Minolta SPAD 502®) were determined for wheat and corn crops (data not shown).

Grain yield data were subjected to analysis of variance for each site/crop. Means separation was carried out by LSD test (p<0.05). Soil variables were related to grain yield and grain yield responses through regression analysis.

Averaged over both crop rotations, balanced fertilization with NPS increased grain yields by 49, 65, 7, and 20% compared to the check yields for corn, wheat, full-season soybean, and double-cropped soybean, respectively (Figures 2 and 3). Application of K, Mg, B, Cu, and Zn generally did not affect grain yields.

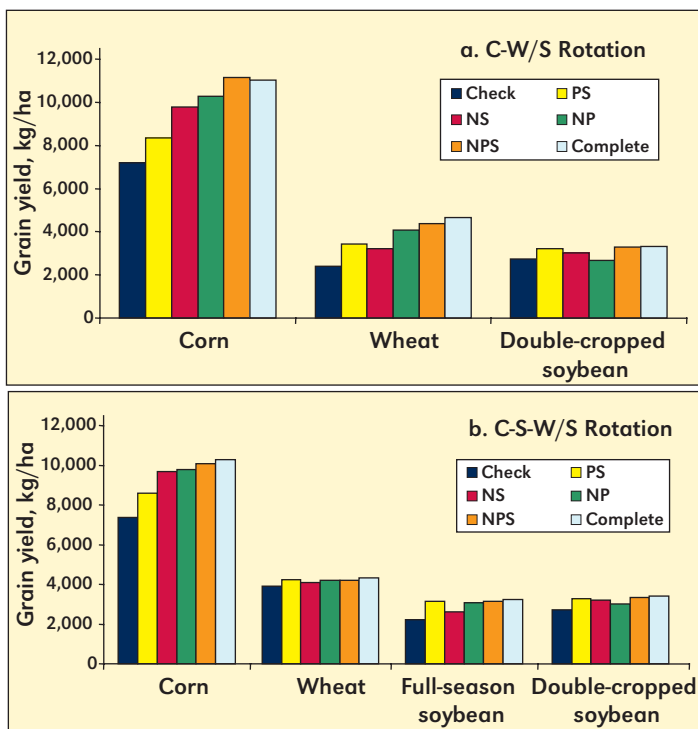


Figure 2. Average grain yields for the C-W/S (a) and C-S-W/S (b) rotations from 2000 to 2006. Nutrition network of CREA Southern Santa Fe.

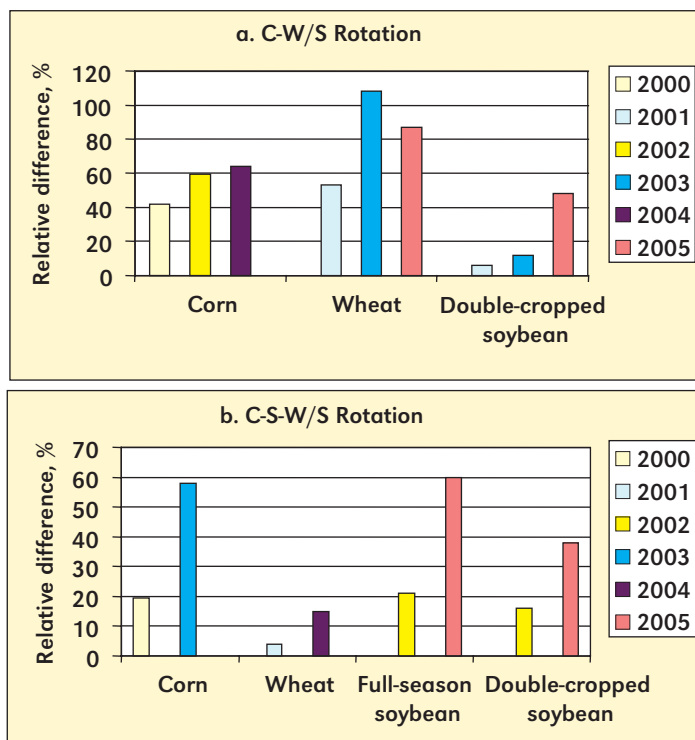


Figure 3. Relative grain yield difference between the NPS and check treatments for the C-W/S (a) and C-S-W/S (b) rotations from 2000 to 2006. Nutrition network of CREA Southern Santa Fe.

For corn, in 23 site/years responses were significant in 21, 8, 6, and 5 site/years for N, P, S, and NPS, respectively. For wheat, responses were significant in 5 of the 16 site/years for N, 11 site/years for P, 3 site/years for S, and 2 site/years for other nutrients. For full season soybean, in 11 site/years responses were significant in 1, 3, 2, and 3 site/years for N, P, S, and NPS, respectively. For double-cropped soybean, responses were significant in 1 of the 16 site/years for N, 3 site/years for P, 10 site/years for S, and 4 site/years for NPS.

Nitrogen response in corn and wheat was significantly related to soil NO₃-N availability at planting plus fertilizer N. Wheat yields of 3,600 kg/ha could be reached with N availability of 100 kg/ha, while corn yields of 10,300 kg/ha could be achieved with 200 kg/ha of N availability.

Phosphorus response was related to soil Bray P-1 for corn, wheat, and double-cropped soybean. Critical levels of soil Bray P-1 were estimated at 15 ppm for corn and wheat, and 13 ppm (at wheat planting) for double-cropped soybean. Responses to S were related to SO₄-S concentration at planting for corn, and full season soybean, but not for wheat (data not shown).

Frequency of responses and yield differences increased along the six seasons of evaluation as a consequence of residual effects that resulted in soil fertility buildup. Figure 3 shows that relative grain yield differences between the NPS and check treatments have increased over the years as a result of improved versus soil nutrient depleting fertilization, respectively. Differences in Bray P-1 were found among treatments with and without P fertilizer, but residual effects of N or S fertilization could not be detected in soil NO₃-N or SO₄-S measurements. Depending on the rotation, average soil Bray P-1 increased by 2 to 3 ppm per year, in the NPS treatment which had an almost neutral P balance between P applied as

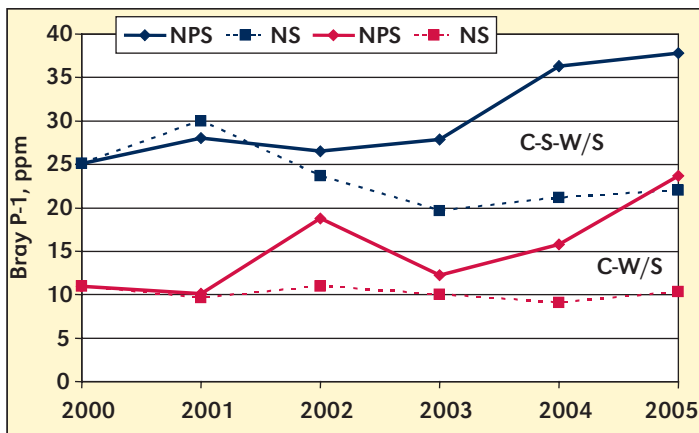


Figure 4. Evolution of soil Bray P-1 of the NPS and NS treatments averages of all sites, of the C-W/S (red lines) and C-S-W/S (blue lines) rotations from 2000 to 2006. Nutrition network of CREA Southern Santa Fe.

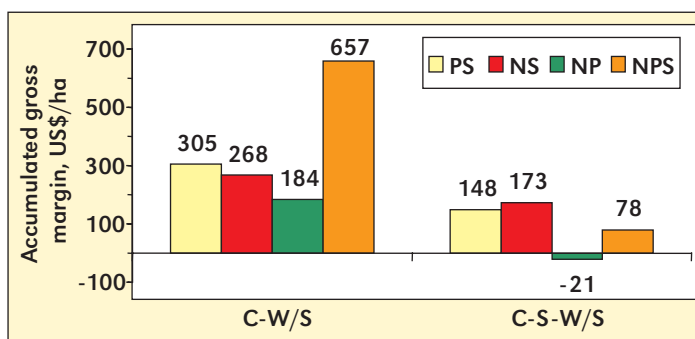


Figure 5. Accumulated gross margin of selected treatments in the 6 years of experimentation for the C-W/S and C-S-W/S rotations. Nutrition network of CREA Southern Santa Fe.

fertilizer and P removed in grains in both rotations (Figure 4). Soil Bray P-1 tended to decrease in the NS treatments by 0.05 to 1.5 ppm per year.

Comparison of SOC concentrations between the check and NPS treatments showed an average increase of 3.4 g C/kg soil after four seasons. However, these changes in SOC were highly variable among sites, from -5.2 to +10.3 g C/kg soil. Fertilization with NPS generally tended to decrease soil

pH, -0.4 to +0.1 units depending on the site. No significant differences in cation and micronutrient concentrations were observed between the check and NPS treatments.

Economical analysis of the first 6 years of the network shows that NPS fertilization at P and S rates equivalent to grain nutrient removal plus 10%, and highly responsive rates for N, could be profitable under the conditions of the CREA Region of Southern Santa Fe. Figure 5 shows that the accumulated gross margin for the 6 years of C-W/S rotation was higher than the C-S-W/S rotation. This could be attributed to the lower soil Bray P-1 levels of the C-W/S sites, and increased crop P demand due to the more frequent appearance of corn and wheat in the rotation. [BC](#)

IPNI Project # ARG-12

Dr. García is Regional Director, IPNI Latin America-Southern Cone, fgarcia@ipni.net. Mr. Boxler, Mr. Minteguiaga, Mr. Pozzi, and Mr. Firpo are with the Southern Santa Fe Region of CREA, Mr. Deza Marin is with Agroservicios Pampeanos (ASP), and Mr. Berardo is with Laboratorio Fertilab-INTA-FCA Balcarce.

References

- Blanco, H., et al. 2004a. *Informaciones Agronomicas* 23:9-14.
- Blanco, H., et al. 2004b. *In Simposio "Fertilidad 2004"* pp. 61-67. INPOFOS Cono Sur. Acassuso, Buenos Aires, Argentina.
- Boxler, M., et al. 2006. Abstracts and Actas CD XX Congreso Argentino de la Ciencia del Suelo. AACs. Salta-Jujuy, 19-22 Septiembre 2006. pp. 279.
- García, F.O., et al. 2005a. *Actas VIII Congreso Nacional de Maíz. AIANBA-Maizar*. Rosario, 16-18 Noviembre 2005. pp. 154-157.
- García, F.O., et al. 2005b. Abstracts VII International Wheat Conference. SAG-PyA-INTA. Mar del Plata, 27 Nov-2 Dic 2005. pp. 186.
- García, F.O., et al. 2006a. *Proceedings CD XVIII World Congress of Soil Science*. IUSS. Filadelfia, EE.UU. Julio 2006.
- García, F.O., et al. 2006b. *AACREA*. 32 pp. ISBN 987-22576-7-1.
- Thomas, A., et al. 2002. *Better Crops International* 16 (2): 6-9.
- Thomas, A., et al. 2003. *Agronomy Abstracts (CD)*. ASA-CSSA-SSSA. Madison, Wisconsin, EEUU.

Acknowledgments

We greatly acknowledge the help and collaboration of all the farmers and farm's staff who may possible this study, and the support of Agroservicios Pampeanos (ASP) since 2000.

International Plant Nutrition Institute Announces the "IPNI Science Award"

IPNI President Dr. Terry L. Roberts recently announced a new program to recognize outstanding achievement in the field of plant nutrition.

"The IPNI Science Award is to be presented each year to one agronomic scientist. Private or public sector agronomists, crop scientists, and soil scientists from all countries are eligible for nomination," Dr. Roberts explained.

The recipient will receive a plaque and a monetary award of US\$5,000 (five thousand dollars). The award recognizes outstanding achievements in research, extension, or education which focus on efficient and

effective management of plant nutrients and their positive interaction in fully integrated crop production that enhance yield potential. The purpose of the award is to acknowledge and promote distinguished contributions by scientists involved with ecological crop intensification where productivity is increased and the environment is improved.

For 2007, nominations for the IPNI Science Award must be received by September 30; winner of the award will be announced December 31. To learn more about this program and to obtain a nomination form, visit the IPNI website at >www.ipni.net/awards<. [BC](#)